Journal of the Royal Society of Western Australia, Vol. 65, Part 4, 1982, pp. 131-141.

The distribution of *Lepidogalaxias salamandroides* and other small fresh-water fishes in the lower south-west of Western Australia

by P. Christensen

Forests Department, Manjimup, W.A. 6258

Manuscript received 21 July 1981; accepted 20 April 1982

Abstract

A survey of small native fishes in the lower south-west of Western Australia indicates that most native species in the area with the possible exception of *Nannatherina balstoni*, are relatively common.

The distribution of *Lepidogalaxias salamandroides* is restricted but the species is common within the area of its occurrence. Its distribution was found to correlate with 'coloured waters', high in organic matter, arising in non-forested areas of low open woodland, herbland, scrubland and heaths which typically occur to the south of the main forest area. The species occurred most frequently in small pools, often seasonal, with a muddy bottom and which were clear of overhanging vegetation. The water in which they occurred was typically of low pH with a high chemical O_2 demand. They were frequently found in association with other species of small fish.

The fish species collected showed a tolerance to a fairly wide range of pH and some, *Edelia vittata* and *Bostockia porosa* in particular, appeared to be tolerant of moderately high salinities.

Introduction

First collected in 1959 the diminutive fresh-water fish, *L. salamandroides* has since created world wide interest amongst zoologists. Its describers, Mees (1961) originally included it in the Galaxiidae, a group of salmoniform fishes, some of which *L. salamandroides* superficially resembles. Its inclusion in that family was subsequently disputed by Scott (1966). Later during a search for a clear indication of the species true relationship (Rosen 1974), it became evident that the classification of salmoniforms was in a confused state. In an extensive review and comparison of salmoniform anatomy, Rosen proposes an entirely new phylogeny for the salmonids and related groups. He suggests that *L. salamandroides* is not a galaxiid, a group he places in the salmoniforms, but an esocoid, a related northern hemisphere group, including the pike of which *L. salamandroides* is now the sole southern hemisphere representative. This classification presents intriguing problems which leads Rosen to speculate further in the wider area of zoogeographic problems in relation to fishes.

Consequently, *L. salamandroides* has become an important species not only in its own right but also because it occupies a unique position as a key piece in the puzzle of phylogeny and zoogeography of the worlds teleost fishes.

The future of this little fish is currently a subject of concern amongst conservationists. The type locality is described by Mees (1961) as, "a very small creek in heavy forest of mixed karri and jarrah, *E. diversicolor* F. V. Mueller and *E. marginata* Sm.". Much of this type of forest occurs within the marri chipwood licence area (Anon. 1977) and is due to be clear felled and regenerated over the next few decades. Other collections of *L. salamandroides* have been made since its original discovery, and the majority have been from within the chipwood licence area. Because of this, concern has been expressed that forest operations may endanger the species.

In order to determine the present status of the species, a survey of its distribution in the lower south-west was carried out during the summers of 1978 and 1979. During the survey it was also attempted to relate the occurrence of the species to site-vegetation type, water quality and other site characteristics.

Information on the distribution of other species of small fishes and crustaceans was also obtained during the survey.

Methods

Preliminary collections and examination of Museum records suggested that *L. salamandroides* was confined to the lower south-west where it had a sub-coastal distribution. Accordingly, the survey was designed to include the middle and lower reaches of the major river systems in this area and extended between the Blackwood river in the west to the Hay river in the east. Sampling points included small streams, rivers, lakes and other bodies of water, both natural and man made such as roadside ditches and drains.

22192—(3)

Figure 1.—Map of the lower south-west showing the distribution of *L. salamandroides*. △ Museum records of *L. salamandroides* collections X Original collection of *L. salamandroides* (Mees 1961) O Sample point ● Sample point with *L. salamandroides* .... Approximate northern extent of southern herbland, scrubland, heath and low open forest and woodland communities.

Sampling was carried out by means of a scoop net. Scooping was continued at each sample point until no new species of fish were caught. Numbers and species of fish and crustaceans netted were recorded and representative samples from each sampling point were sent to the Western Australian Museum for identification.

A total of 120 sampling points (Fig. 1) were visited during January and February in 1978 and 1979. At this time of the year water in the streams is low, making sampling easier and more effective. At each sampling point a measure of the abundance and frequency of the major plant species growing in the immediate vicinity was obtained using a qualitative five point scale of frequency to give a cover value for each species (Havel 1975). In addition to the vegetation data, ten parameters relating to sample site characteristics, and six to water quality were recorded at each sampling point. (Appendix 1.)

Principle components analysis was used to achieve ordination of the sampling points, based on vegetation data, using the programme FACVA (Havel 1975). This programme combines the loadings of the vegetation species on the component axes with their cover values at individual points to obtain scores which can be used as point co-ordinates. A sampling points co-ordinate (score) on any component axis is the sum, for all species, of the products of their loadings on that component, and the deviation of their cover value on that point from their mean cover value in the study as a whole. Varimax rotation was used to obtain best alignment of the component axes. Square root transformation was employed to achieve the best possible separation of the data. Data on the occurrence of fish species as well as those relating to sample site characteristics and water quality were examined in relation to sampling point distribution within the principle component matrix in order to identify any trends in the various parameters relating to the distribution of fish species.

Results

Lepidogalaxias salamandroides

Lepidogalaxias salamandroides with a frequency of occurrence of 16.7%, was not one of the most frequently netted species but it is relatively abundant in waters to the south of the main karri forest area and was collected in reasonable numbers at most sampling stations where it was found (Appendix 2.)

Almost all of the sampling points where it was caught fall within the area of non-forested low open woodland, herbland, scrublands and heath in the high rainfall areas to the south of the main forest belt (Fig. 1).

Results of ordination suggests a pattern of distribution which is related to the major vegetation associations of the area. Ordination of the streamside vegetation resulted in three quite distinctive groupings (Fig. 2); a southern jarrah forest streamside vegetation type (1), a karri forest streamside vegetation type (2) and a non-forest vegetation type (3). Ordination of the sampling points using plant species loadings achieved good separation on factors 1 and 2, these two factors representing 22.4 and 10.4 percent of the total variance respectively. However, no attempt was made to interpret the principal component axes, these were used merely as a framework within which to identify trends in the recorded parameters relating to fish species occurrence.

The sampling points at which *L. salamandroides* was collected mostly occur towards the negative end of the factor 1 axis in the southern jarrah and non-forest associations (Fig. 3a). Using the CHI square test *L. salamandroides* was found to be positively associated with plant species typical of these non-forested areas and southern jarrah associations and negatively associated with plant species of the karri forest (Table 1).

Further CHI square tests also revealed significant correlations between *L. salamandroides* occurrences and some of the recorded site characteristics and measures of water quality. It was found to be positively correlated with waters of <pH 5.0* and > 100 gm/l suspended solids* and small pools < 1 m across***. There was a negative correlation with the presence of aquatic vegetation*. (*Signif. 0.05 level; ***Signif. 0.001 level.)

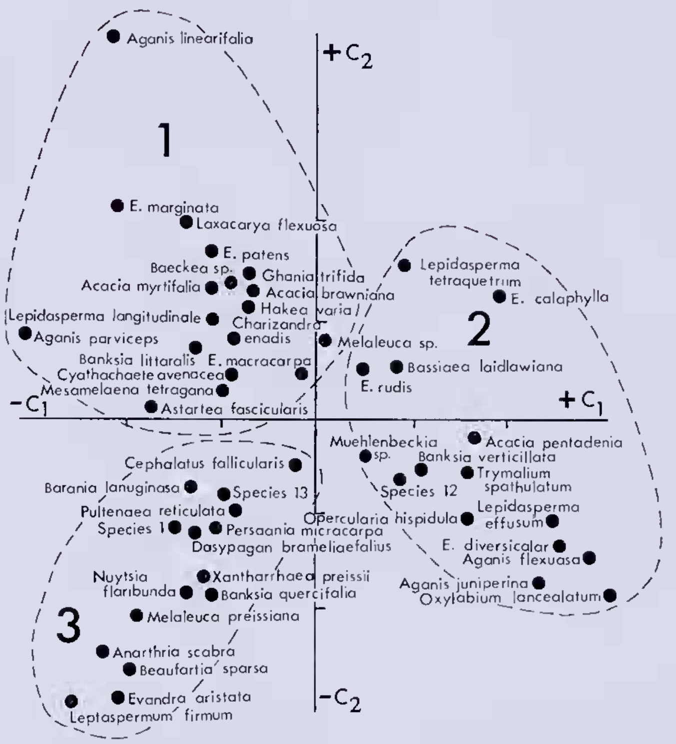


Figure 2.—Distribution of 48 individual plant species recorded at 120 points within component space derived by P.C.A., Components 1 and 2. (Square root transformation was used.) Note the separation of three major forest streamside plant communities; 1 = Southern jarrah forest 2 = Karri forest 3 = Southern herbland, scrubland, heath and low open forest and woodland communities.

Table 1

Plant species significantly* correlated with the presence of *L. salamandroides* and other small fish in the study area
*correlation signfic. at 0·05 level (CHI sq. test)

Plant species, "associations"	Fish species			
	Bostockia porosa	*Edelia vittata*	*Galaxiella munda*	*Lepidogalaxias salamandroides*
1. Southern Jarrah Forest Associations				
Acacia myrtifolia	+		+	
Acacia strigosa	+	+		
Agonis parviceps				+
Cyathochaete avenacea				+
Eucalyptus patens			+	
Hakea varia				+
Lepidosperma longitudinale			+	
Mesomelaena tetragona				+
2. Karri Forest Associations				
Agonis flexuosa			—	—
Agonis juniperina		+		
Banksia verticillata	+	+		
Eucalyptus diversicolor		+		
Eucalyptus calophylla				—
Lepidosperma effusum		+		—
Opercularia hispidula				+
Oxylobium lanceolatum		+		—
Species 12		—		
3. Southern Flats Associations				
Banksia quercifolia				+
Beaufortia sparsa			+	
Dasypogon bromeliaefolius				+
Evandra aristata				+
Leptospermum firmum				+
Persoonia microcarpa				+
Species 1			+	+

The water at sampling points in the sector of the component space in which most *L. salamandroides* occurrences were recorded was found to have a tendency towards low pH, high colouration and a high permanganate equivalent. The latter being a measure of chemical O_2 demand which in most cases is indicative of the organic matter content of the water (Fig. 4).

Other species

The distribution of the other species of small fish netted during the survey was examined in a similar manner to that of *L. salamandroides*.

Edelia vittata with a frequency of occurrence of 40.8 percent was the most common species and shows a slight tendency to occur at sampling points within that sector of the component space characterized by the karri forest associations (Fig. 3b). This trend is supported by positive correlation with plant species typical of these associations (Table 1). The The second most common species *Bostockia porosa*, frequency 33.8 percent exhibits no clear trends in its distribution (Fig. 3c) and is correlated with very few plants species (Table 1). The distribution of *Galaxiella munda* with a frequency of 30.8 percent, is most similar to that of *L. salamandroides*, showing a tendency to occur at sampling points in the jarrah and non-forest associations (Fig. 3d). This trend is supported by positive correlations with plant species from these associations.

The other small fish species *Galaxias occidentalis*, *Nannatherina balstoni* and *Galaxiella nigrostriatus*, occurred at frequencies too low to allow any assessment of their preferred habitat. *Galaxias occidentalis* with a frequency of 10.8% may be more common in the study area, but it is a strong swimming species which prefers the larger streams and it may well have escaped the net on occasions.

In addition to the above, two small fingerling brown trout *(Salmo trutta)* and a young ammocoete stage lamprey *(Geotria australis)* were netted in a small tributary of the Warren River. The trout were observed swimming rapidly in fast flowing

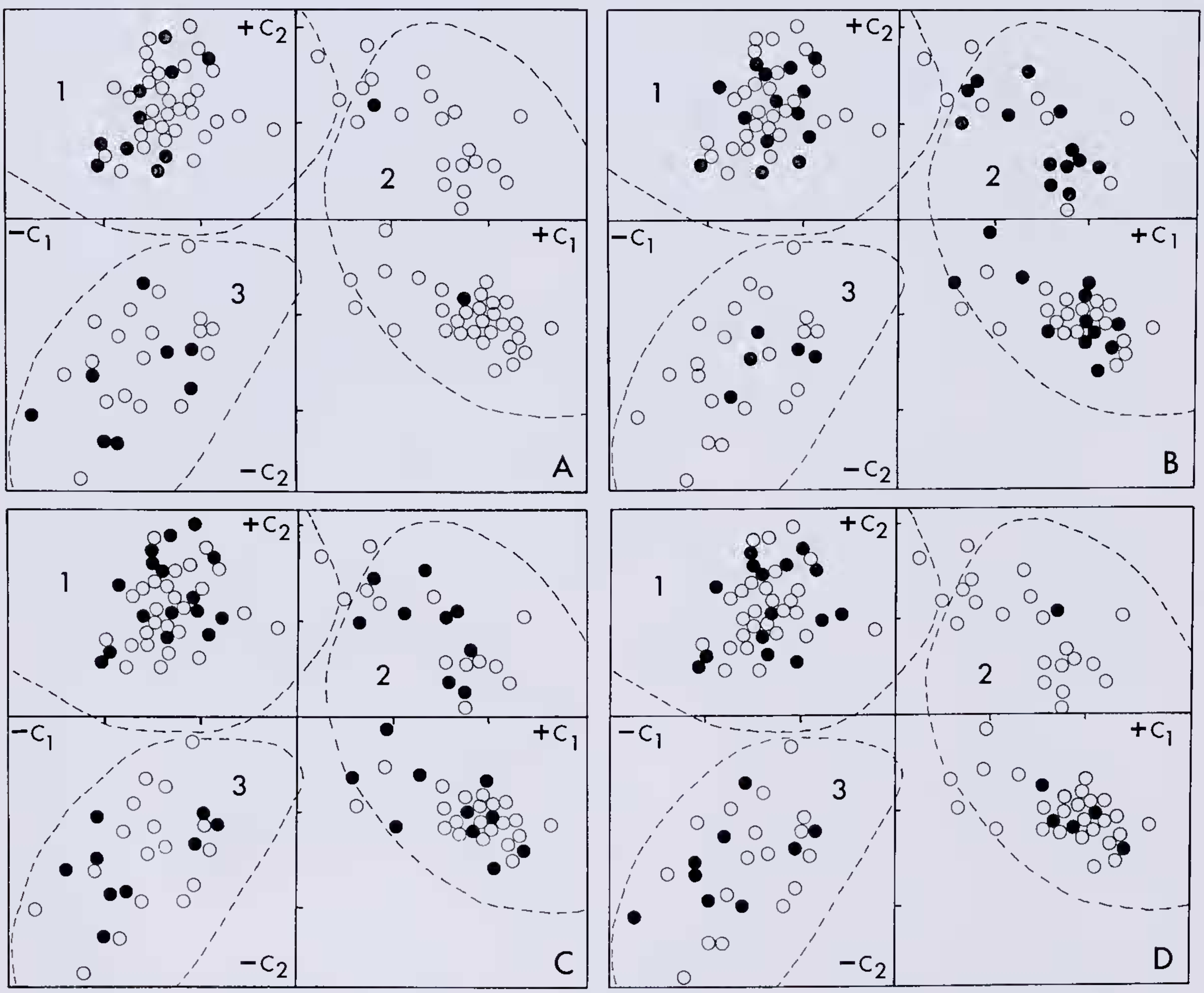
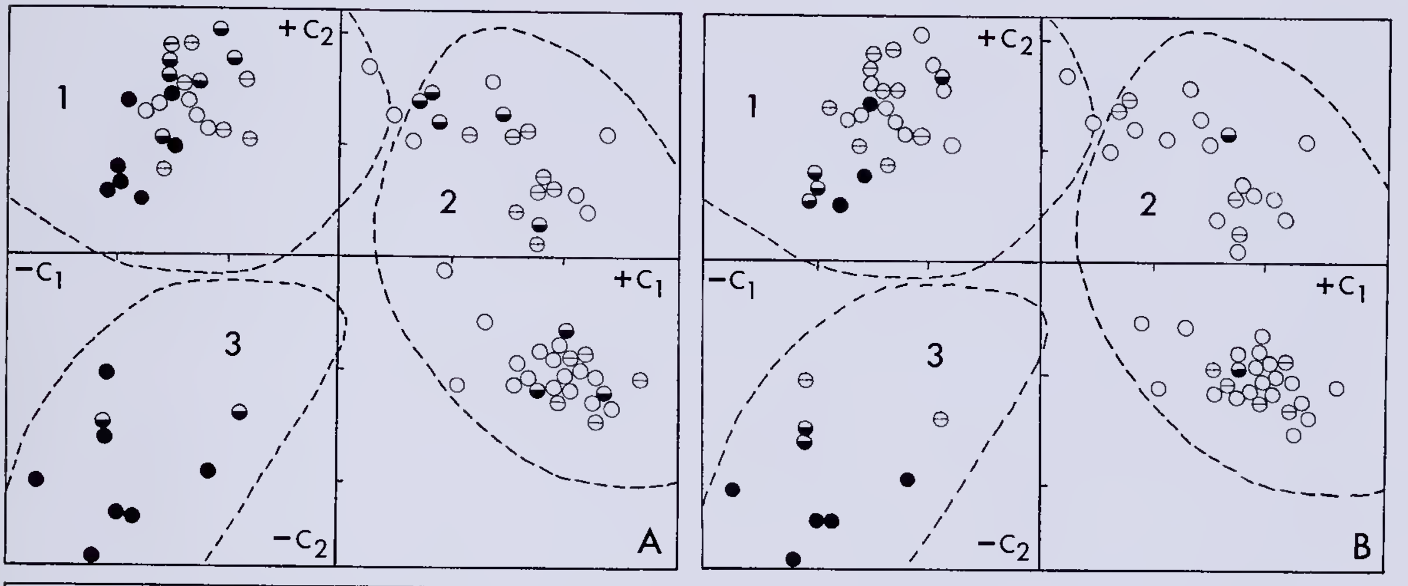


Figure 3.—Distribution of *L. salamandroides* and other small fishes from 120 sampling points within component space derived by P.C.A., of vegetation species data, Components 1 and 2. (Square root transformation was used.) 3 (a) *L. salamandroides* 3 (b) *E. vittata* 3 (c) *B. porosa* 3 (d) *G. munda*. O = sample point • = sample point with fish.



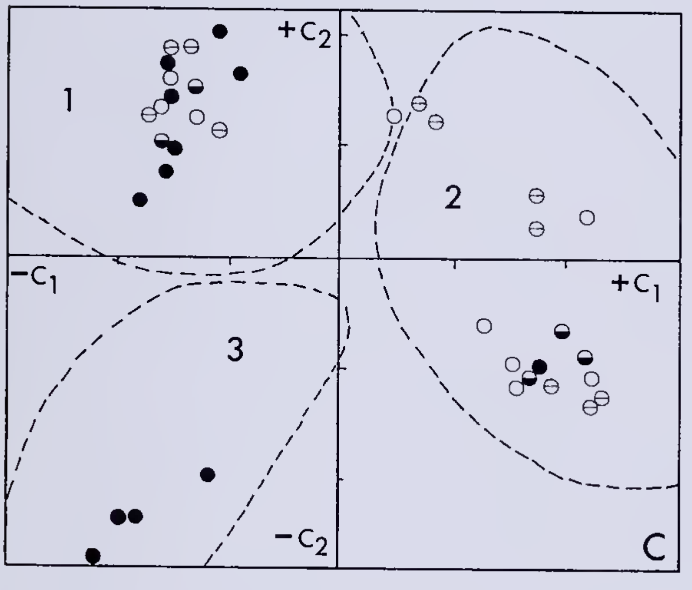


Figure 4.—Selected water quality measures plotted on 82 sampling points distributed within component space derived by P.C.A., of vegetation species data, Components 1 and 2. (Square root transformation was used.) Note the distinct trends exhibited by each of these water quality measures. 4 (a) pH 4 (b) colour 4 (c) permanganate equivalent

4(a) ○ 7·0+
⊖ 6·0—6·9
◒ 5·0—5·9 pH
● 3·5+

4(b) ● > 1 000
◒ 500—999
○ 250—499 colour
○ <249

4(c) ● 4+
◒ 3—3·9
⊖ 2—2·9 permanganate equivalent
○ <2

cold water in a sandy creek bed. Seventeen *Gambusia affinis,* the only specimens of this species caught during the survey, were netted at one sampling point on the Frankland River. *Nannatherina balstoni* was netted at only four points and *Galaxiella nigrostriatus* at only two.

Discussion

Lepidogalaxias salamandroides has a restricted range but it is comparatively abundant in the pools in which it does occur. The waters of the streams within the area of occurrence of *L. salamandroides* arise in non-forested areas of low open woodland, herblands, scrublands and heaths as defined by Smith (1973). These vegetation associations all occur on peaty sandy soils. Around Denmark, these soils are typically leached sands or black peaty sands of the Kwilalup and Plantagenet peaty sands series of Hosking and Burvill (1938). In the west they are similar sands of the Chudalup and Blackwater associations of McArthur and Clifton (1975). Drainage on these sands is impeded and low lying areas are subject to prolonged winter flooding and waterlogging Smith (1973). The waters of this area are characteristically brown in colour, stained with the exudates of organic matter, they have a low pH and a high chemical oxygen demand, probably a consequence of the high organic matter content.

Whether *L. salamandroides* is collected from the streams and waters within areas of southern jarrah forest or in the non-forested areas themselves it is in these dark stained waters in which it most frequently occurs. During summer they are most often located in small pools or slow flowing small streams in association with other species but in winter they may also be found widespread over the herblands and scrublands which are under water at this time (Pusey 1981). The pools in which the fish occurred most often were clear of overhanging vegetation, had a muddy bottom and were never clean sand or rock. They were often seasonal, supporting the findings of Pusey (1981) that the species aestivates over summer. The absence of water weed and the freshwater shrimp *Paleonetes australis* appears to be another characteristic of these waters.

The area sampled did not include the known easternmost occurrence of *L. salamandroides*. There is a W.A. Museum record (P 25693.001 coll.

J. Allen 1976) from Lake Powell east of Albany. The area surrounding this lake is low open woodland and sedgelands similar to those in the survey area. It is likely that this record is close to the species eastern limit of distribution since the climate and vegetation change markedly further to the east. Similarly it seems unlikely that the fish will be found within the jarrah forests to the north of the karri forest area. Collections within the karri forest itself are infrequent and appear to be associated with waters which arise in peaty heathland areas which occur within the southern portion of the karri forest. Such is the case with the collection made at point 34 on this survey and also the original collection (Mees 1961) which appears to have been made in a stream originating in low open woodland on grey peaty sands in the vicinity of Gobblecannup swamp to the northeast of Shannon.

No two fish species were found to be significantly associated although several species were usually netted together at most sampling points (Appendix 2). The most frequently collected small fishes in the survey area were *Edelia vittata*, *Bostockia porosa* and *Galaxiella munda*, all occurring at more than 30 percent of the sampling points. *Edelia vittata* was collected from both still and running water including rivers, lakes, small creeks, ponds and roadside drains. Its occurrence was found to be significantly correlated (.001 level) with the presence of aquatic vegetation. *Bostockia porosa* and *Galaxiella munda* occurred most frequently in smaller streams, pools and roadside drains. The latter species was the only one of the small fishes, with the exception of *L. salamandroides*, which showed a distinct distribution pattern (Fig. 3) very similar to that of *L. salamandroides*. It is significant that this species, like *L. salamandroides* has a very limited distribution (McDowall 1978; McDowall and Frankenbury 1981). With the exception of one outlying population near Gin Gin, to the north of Perth, the species is restricted to the high rainfall areas of the southern forests.

The other species of small fishes, *Galaxias occidentalis*, *Nannatherina balstoni* and *Galaxiella nigrostriatus*, all occurred at comparatively low frequencies. *Galaxias occidentalis* is widely distributed in the area but infrequently caught probably because it is a fast moving fish inhabiting the larger pools, and faster flowing streams and rivers. *N. balstoni* appears to be comparatively rare despite the fact that the survey area covered a major portion of its known range between Two Peoples Bay and the Blackwood River, Coy (1979). *Galaxiella nigrostriatus* likewise is uncommon but the survey area may represent only the western extremity of this species range which Coy (1979) gives as Esperance to Albany, although McDowall (1978) lists a collection from Wye plains southeast of Shannon.

There was considerable difference in preference for pH ranges shown by native fish species. This ranged from *G. occidentalis* which preferred the more neutral waters to *L. salamandroides* showing a distinct preference for more acidic waters (Fig. 5). The range of tolerance shown by all species is comparatively wide. At least four of the fish, *E. vittata*, *B. porosa*, *G. munda* and *G. occidentalis* appeared to have some tolerance to salinity. All occurred together in a pool on the Tone River (No. 56)

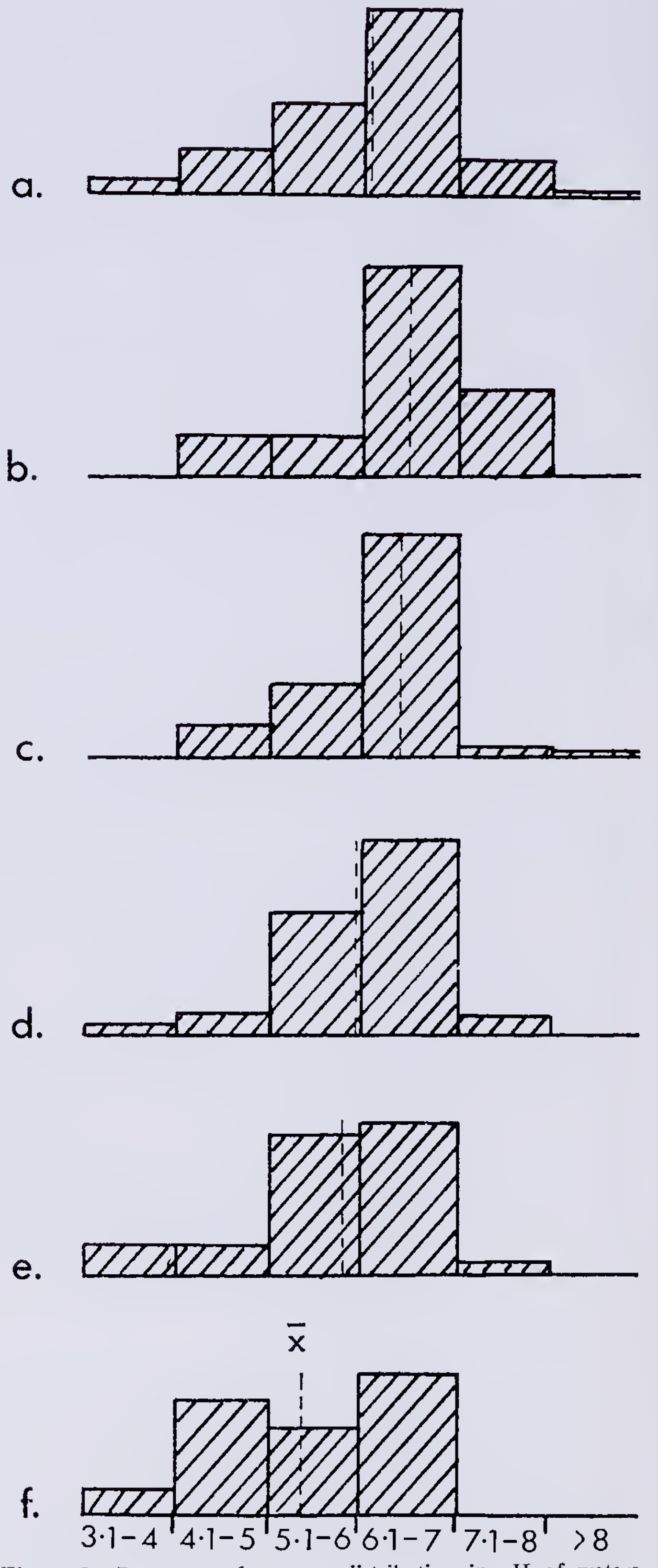


Figure 5.—Percentage frequency distribution in pH of waters inhabited by small native fish species collected during the survey.

5 (a) pH distribution $\bar{x}$ 6.06, range 3.7-8-4, n = 83.
5 (b) *G. occidentalis* $\bar{x}$ pH 6.48, range 4.4-7.6, n = 9.
5 (c) *E. vittata* $\bar{x}$ pH 6.39, range 4.2-8.4, n = 35.
5 (d) *B. porosa* $\bar{x}$ pH 6.05, range 3.9-7.6, n = 34.
5 (e) *G. munda* $\bar{x}$ pH 5.79, range 3.9-7.6, n = 24.
5 (f) *L. salamandroides* $\bar{x}$ pH 5.40, range 3.7-6.8, n = 13.

with a conductivity of 5202, equivalent to 3620 T.D.S. (Hatch 1976). *E. vittata* and *B. porosa* both occurred together in a small creek on the Denbarker Road (No. 59) with a conductivity of 7159, (equivalent T.D.S. = 4992) and *E. vittata* was collected at one point on the Frankland River (No. 78) with a conductivity of 8129 (equivalent T.D.S. = 5672). *L. salamandroides* appears to be less tolerant. The highest conductivity, 644 (equivalent T.D.S. = 425), recorded for water in which this species occurred was at point 82, a small creek on Middle Road in the Bow river catchment.

The five most frequently collected fish, *E. vittata, B. porosa, G. munda, L. salamandroides* and *G. occidentalis* were all collected in streams and pools on cleared farmland areas. A total of 10 sampling points out of 16 on farmland in the Nornalup, Barlee Brook, Denbarker, Denmark, Scott River, Northcliffe and Muir Highway areas contained fish in reasonable numbers. Their frequency was consistent with the overall frequency of the species. Thus *E. vittata* and *B. porosa* occurred at 7 points, *G. munda at 4* and *L. salamandroides* and *G. occidetalis* at one each. Many of the sample points were in areas which have been cleared for some time and dense growths of green algae and water weed were often present. How long populations of native fishes can continue to survive under such conditions is not known.

Many of the small streams and waters of the south arise and flow within state forest and here their future would seem to be secure. The water remains fresh and there is no indication that forest operations such as for example those associated with the woodchip industry, have affected the quality of the regions water resources to any level which provides a basis for concern (Annon. 1980). A more likely threat than mans activities in this area is that of introduced competitors.

The capture of the small introduced fish *G. affinis* at only one sampling point, on the Frankland river, confirms the comments of Coy (1979), that this species is not common in many of the south-coastal streams. With this exception and a record from the Warren river Mees (1977), this species appears to be absent from the streams of the forested area between the Blackwood and the Hay river. There is a strong possibility that it may spread through this area in the future.

Several authors Coy (1979), Mees (1977) and Sarti and Allen (1978) have expressed fears that the presence of this fish leads to the extinction of species of small native fish. There appears to be no evidence from Western Australia to substantiate such claims. *Gambusia affinis* is known to occur in association with native species at several localities Mees (1977), Sarti and Allen (1978) and Forests Department (unpublished data). However no records exist to indicate what species were present at these localities prior to the introduction of *G. affinis*. In the absence of such data, any suggesting that the fish fauna has become impoverished, remains speculative. Nevertheless until proven otherwise it would be prudent to regard the species as a threat to small native fishes in the area.

In conclusion it seems unlikely that *L. salamandroides* is threatened by any of mans activities. There is no evidence to suggest that forestry practices pose any problems, in addition the waters in which the species occurs most often arise and flow through areas of non-commercial forest not subject to logging activities. Agricultural clearing is not likely to be a problem since there is little uncommitted land outside National Parks and State Forests in the area. Likewise mans activities would seem to pose no problem to other species of small fish in the area.

The most obvious threat to any of these native fishes would appear to be *G. affinis*. This however remains to be demonstrated and field ecology studies are urgently needed on all species to answer this question. The indication that some species may be able to co-exist with *G. affinis* and that some appear reasonably tolerant to changes in water quality such as salinity, are encouraging. The genera *Lepidogalaxias, Bostockia* and *Nannatherina,* the species of galaxiids and *Edelia vitatta* are all endemic to the south-west and deserve more attention than they have had in the past.

Acknowledgements.—I would like to thank all those who helped in the survey, in particular Grant Wardell-Johnson, Ian Kealey, Graeme Liddelow and Chris Vellios, Elizabeth Bartuccio and Karan Maisey who drafted the figures. I am also grateful to Allan Hatch and his staff at the Institute of Forest Research Como for the chemical analysis of the water samples and to the W.A. Museum for identification of the fish and crustacea specimens.

References

Anon. (1977).—General Working Plan No. 86 of 1977.

Anon. (1980).—Report by the Steering Committee on Research into the effect of the Woodchip Industry on Water Resources in South Western Australia. *Dept. Cons. and Env. Bull.* **81**.

Beard, J. S. (1979).—The vegetation of the Albany and Mt. Barker areas Western Australia. Veg. map Publication Perth.

Coy, N. J. (1979).—Freshwater fishing in south-west Australia. Jabiru books.

Hatch, A. B. (1976).—Some chemical properties of forest stream waters in Western Australia. *For. Dept. W.A. Bull.* **89**.

Havel, J. S. (1975).—Site—vegetation mapping in the Northern jarrah forest (Darling Range). 1.—Definition of site—vegetation types. *For. Dept. W.A. Bull.* **86**.

Hosking, J. S. and Burvill, G. H. (1938).—A soil survey of part of the Denmark Estate Western Australia. *Comm. Sci. Ind. Res. Aust. Bull. No.* **115**.

McArthur, W. M. and Clifton, A. J. (1975).—Forestry and agriculture in relation to soils in the Pemberton area of Western Australia. *Soils and Land Use Series No.* **54**, C.S.I.R.O., Australia.

McDowall, R. M. (1978).—A new Genus and species of Galaxiid fish from Australia (Salmoniformes: Galaxiidae). *J. Roy. Soc. N.Z.* **8**: 115-124.

McDowall, R. M. and Frankenburg, R. S. (1981).—The Galaxiid fishes of Australia. *Records Aust. Mus.* **33**.

Mees, G. F. (1961).—Description of a new fish of the family Galaxiidae from Western Australia. *Journ. Roy. Soc. of W.A.* **44**: 33-38.

Mees, G. F. (1977).—The status of *Gambusia affinis* (Baird and Girard) in south Western Australia. *Rec. West. Aust. Mus.* **6**: 27-31.

Pusey, B. J. (1981).—The Life history of the Shannon Mud Minnow *Lepidogalaxias salamandroides* (Mees) with special reference to aestivation. Unpub. Hons. Thesis Zoo. Dept. Uni. of W.A.

Rosen, D. E. (1974).—Phylogeny and zoogeography of salmoniform fishes and relationships of *Lepidogalaxias salamandroides*. *Bull Amer. Mus. Nat. Hist.* **153**: 269-325.

Sarti, N. L. and Allen, G. R. (1978).—The freshwater fishes of the Northern Swan Coastal Plain. *In* Faunal studies of the Northern Swan Coastal Plain, W.A. Museum publn.

Scott, E. O. G. (1966).—The genera of Galaxiidae. *Australian Zoologist* **13**: 244-258.

Smith, F. G. (1973).—Vegetation survey of Western Australia. W.A. Dept. of Agriculture.

Appendix 1

Data recorded at each sampling point.

1. The main plant species at each sampling point were scored on a five point scale of frequency; (Havel 1975).
   0—Absent
   1—Very rare, seen only after careful search
   2—Present, observable, but in small numbers
   3—Common locally, but not uniform over the whole area
   4—Common over the whole area
   5—Completely dominating the undergrowth

2. Numbers of each species of fish and crustaceans caught at each point was recorded and samples were collected and sent to the W.A. Museum for identification.

3. Site characteristics,
   1. Pool size (diam.) < 1 m, 1-2 m, 2-4 m, > 4 m.
   2. Natural or man made i.e. dozer scoop, ditch etc.
   3. Degree of overhead shade 0 = open 1 = ½ shade
      2 = fully shaded
   4. Running water or still.
   5. Sample point—0 = small flat, 1 = medium sized flat, 2 = extensive flat, 3 = non-forest area, 4 = small stream, 5 = stream, 6 = river, 7 = lake.
   6. Forest type,
      1 = jarrah 2 = blackbutt 3 = marri
      4 = cleared farmland 5 = River gums (*Eucalyptus rudis*) 4 = karri
   7. Presence of aquatic vegetation—largely *Chara* or *Nitella sp.*
   8. Streamside soil 0 = rock 3 = peat
      1 = sand 4 = clay
      2 = loam
   9. Stream bottom 0 = rock 3 = peat
      1 = sand 4 = clay
      2 = silt

4. Water quality, Samples were collected and tested in the laboratory for the following; (Only done on sample points 1-84)
   1. pH
   2. Conductivity
   3. Suspended solids (ppm)
   4. Colour (pt—Co units)
   5. Permanganate Equivalent (meP-1).

Appendix 2a

Fishes and crustacea collected at 120 sampling points

Sample Point Number	*Bostockia porosa*	*Edelia vittata*	*Galaxiella nigrostriatus*	*Galaxias occidentalis*	*Galaxiella munda*	*Lepidogalaxias salamandroides*	*Nannatherina balstoni*	*Geotria australis*	*Gambusia affinis*	*Salmo trutta*	*Cherax preissii*	*Cherax quinquecarinatus*	*Paleonetes australis*
1	....	1	....	....	....	....	....	....	....	....	2	....	....
2	....	....	....	....	....	....	....	....	....	....	....	....	....
3	....	....	....	....	....	....	....	....	....	....	....	....	....
4	....	4	....	....	....	8	....	....	....	....	....	....	....
5	7	6	....	....	....	8	....	....	....	....	7	....	....
6	....	11	....	....	1	....	....	....	....	....	....	....	....
7	....	5	....	....	....	....	....	....	....	....	....	....	....
8	1	....	....	....	....	....	....	....	....	....	....	....	....
9	....	....	....	....	....	....	....	....	....	....	2	....	....
10	....	....	....	....	....	....	....	....	....	....	1	....	....
11	....	....	....	....	....	....	....	....	....	....	....	....	....
12	....	....	....	....	....	....	....	....	....	....	2	....	....
13	....	....	....	....	....	....	....	....	....	....	....	....	....
14	2	15	....	....	3	....	....	....	....	....	4	1	....
15	....	....	....	....	2	6	....	....	....	....	9	....	....
16	....	....	....	....	....	....	....	....	....	....	....	....	....
17	....	3	....	....	....	....	....	....	....	....	2	....	....
18	....	....	1	....	....	3	....	....	....	....	24	....	....
19	....	....	20	....	....	....	....	....	....	....	10	....	....
20	7	6	....	....	....	....	....	....	....	....	13	1	6
21	....	....	....	....	....	4	....	....	....	....	12	....	....
22	1	....	....	....	....	2	....	....	....	....	9	....	....
23	9	2	....	....	....	11	....	....	....	....	24	....	....
24	4	4	....	....	7	....	....	....	....	....	7	....	....
25	1	....	....	....	....	....	....	....	....	....	14	....	....
26	....	....	....	1	....	....	....	....	....	....	5	....	....
27	....	1	....	....	....	....	....	....	....	....	....	....	....
28	3	....	....	....	1	....	....	....	....	....	6	....	....
29	1	....	....	....	39	....	....	....	....	....	7	....	....
30	....	2	....	....	....	....	....	....	....	....	....	7	....
31	....	....	....	2	....	....	....	....	....	....	1	....	....
32	....	1	....	....	....	....	....	....	....	....	....	....	....
33	....	7	....	....	....	....	....	....	....	....	2	....	....
34	....	....	....	....	....	2	....	....	....	....	16	....	....
35	....	....	....	....	....	....	....	....	....	....	19	....	....
36	....	....	....	....	9	....	....	....	....	....	....	....	....
37	....	....	....	....	....	....	....	....	....	....	11	....	....
38	....	2	....	....	....	....	....	....	....	....	15	....	8
39	2	1	....	....	....	....	....	....	....	....	....	1	....
40	....	....	....	1	....	....	....	....	....	....	1	....	1

Appendix 2a—*continued*

Sample Point Number	*Bostockia porosa*	*Edelia vittata*	*Galaxiella nigrostriatus*	*Galaxias occidentalis*	*Galaxiella munda*	*Lepidogalaxias salamandroides*	*Nannatherina balstoni*	*Geotria australis*	*Gambusia affinis*	*Salmo trutta*	*Cherax preissii*	*Cherax quinquecarinatus*	*Paleonetes australis*
41	6	2	....	3	....	....	....	....	....	....	24	....	....
42	11	6	....	....	....	....	....	....	....	....	3	....	....
43	....	....	....	....	....	....	....	1	....	2	12	....	1
44	....	....	....	....	....	....	....	....	....	....	....	....	....
45	4	....	....	....	....	....	....	....	....	....	7	....	....
46	....	1	....	....	....	....	....	....	....	....	....	....	....
47	1	2	....	1	13	....	....	....	....	....	3	....	....
48	2	1	....	1	....	9	....	....	....	....	9	....	....
49	3	....	....	....	5	....	....	....	....	....	3	....	....
50	....	....	....	....	....	....	....	....	....	....	....	....	....
51	2	1	....	....	....	....	....	....	....	....	....	....	....
52	....	....	....	....	....	....	....	....	....	....	5	....	1
53	12	1	....	....	9	....	....	....	....	....	1	1	12
54	....	....	....	6	40	....	....	....	....	....	10	....	....
55	6	....	....	....	30	....	20	....	....	....	2	....	....
56	1	3	....	1	1	....	....	....	....	....	6	....	10
57	....	....	....	....	....	....	....	....	....	....	....	....	....
58	....	....	....	....	....	....	....	....	....	....	6	....	50
59	2	1	....	....	....	....	....	....	....	....	17	....	....
60	....	....	....	....	....	....	....	....	....	....	21	....	....
61	3	2	....	....	3	....	....	....	....	....	10	....	....
62	....	....	....	....	2	....	....	....	....	....	....	....	....
63	2	....	....	....	....	....	....	....	....	....	....	....	....
64	5	9	....	1	5	2	....	....	....	....	6	....	....
65	5	11	....	....	....	....	....	....	....	....	2	....	....
66	....	7	....	....	....	....	....	....	....	....	6	2	....
67	13	....	....	....	1	....	....	....	....	....	3	....	....
68	25	4	....	....	9	....	....	....	....	....	3	....	....
69	....	1	....	....	....	....	....	....	....	....	11	....	....
70	6	6	....	....	....	....	....	....	....	....	8	....	....
71	....	....	....	....	....	....	....	....	....	....	....	....	....
72	....	....	....	....	....	....	....	....	....	....	....	....	....
73	....	....	....	....	....	....	....	....	....	....	8	....	....
74	....	....	....	....	1	2	....	....	....	....	24	....	....
75	....	....	....	....	....	....	....	....	....	....	8	2	....
76	....	2	....	....	....	....	....	....	....	....	1	3	....
77	1	3	....	....	4	....	....	....	....	....	24	1	....
78	....	1	....	....	....	....	....	....	....	....	....	....	2
79	....	....	....	....	....	4	....	....	....	....	8	....	....
80	5	....	....	....	....	....	....	....	....	....	7	....	....
81	4	....	....	....	7	....	....	....	....	....	7	....	....
82	....	....	....	....	2	4	....	....	....	....	16	....	....
83	5	6	....	....	3	....	....	....	....	....	9	1	....
84	18	....	....	....	45	....	....	....	....	....	11	....	....
85	....	2	....	....	....	....	....	....	....	....	2	....	....
86	....	13	....	....	4	....	....	....	....	....	....	....	....
87	10	5	....	....	....	....	....	....	....	....	8	....	....
88	....	....	....	....	20	....	....	....	....	....	1	....	....
89	....	....	....	....	1	2	....	....	....	....	....	....	....
90	9	2	....	....	1	1	....	....	....	....	....	....	....
91	....	....	....	....	....	....	....	....	....	....	1	....	....
92	10	....	....	....	30	....	....	....	....	....	26	....	....
93	52	90	....	....	82	....	....	....	....	....	....	....	....
94	....	....	....	....	....	....	....	....	....	....	10	....	....
95	....	....	....	....	....	....	....	....	....	....	2	....	....
96	....	5	....	....	....	....	....	....	....	....	....	....	....
97	....	....	....	....	....	....	....	....	17	....	1	....	3
98	....	....	....	....	....	....	....	....	....	....	10	....	....
99	....	8	....	1	....	13	....	....	....	....	6	....	....
100	....	....	....	....	12	1	....	....	....	....	3	....	....
101	....	....	....	....	....	12	....	....	....	....	20	....	....
102	....	....	....	....	1	....	....	....	....	....	1	....	....
103	....	....	....	....	1	5	....	....	....	....	50	....	....
104	....	....	....	....	....	....	....	....	....	....	4	....	....
105	....	11	....	....	5	....	1	....	....	....	5	....	....
106	10	....	....	....	....	....	....	....	....	....	6	....	....
107	2	1	....	....	....	....	....	....	....	....	3	....	....
108	....	....	....	....	....	2	....	....	....	....	20	....	....
109	....	....	....	....	....	....	....	....	....	....	4	....	....
110	....	....	....	....	....	....	....	....	....	....	1	....	....
111	3	4	....	1	....	....	....	....	....	....	....	....	....
112	20	....	....	....	....	....	20	....	....	....	2	....	....
113	2	1	....	....	....	....	1	....	....	....	2	....	....
114	....	2	....	....	....	....	....	....	....	....	2	....	....
115	12	6	....	....	20	....	....	....	....	....	6	....	....
116	....	....	....	....	....	....	....	....	....	....	1	....	....
117	2	....	....	....	15	....	....	....	....	....	6	....	....
118	....	....	....	1	....	....	....	....	....	....	12	....	....
119	1	....	....	....	4	....	....	....	....	....	9	....	....
120	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	313	291	21	22	438	101	42	1	17	2	750	20	94
Presence	46	49	2	13	37	20	4	1	1	1	88	10	10
% frequency	33·8	40·8	1·7	10·8	30·8	16·7	3·3	0·8	0·8	0·8	73·3	8·3	8·3
Abundance	6·8	5·9	10·5	1·7	11·8	5·1	10·1	1·0	17·0	2·0	8·5	2·0	9·4

Appendix 2b

Description of Sampling Points

R = River	M.P. = Man-Made Pool
C = Creek or stream	C.F. = Cleared Farmland
L.F. = Large Flat*	J = Jarrah
M.F. = Medium Flat	J/M = Jarrah/Marri
S.F. = Small Flat	K = Karri
P = Pool	K/M = Karri/Marri

* Flat = Area of non-forested sedgeland

1.	Ant Pool, J.	116°24'E, 34°44'S
2.	M.P., Nelson Road, S.F.	116°22'E, 34°46'S
3.	C, Nelson Road, J.	116°23'E, 34°43'S
4.	C, Nelson Road, L.F.	116°21'E, 34°43'S
5.	C, Nelson Road, L.F.	116°31'E, 34°41'S
6.	C, Nelson Road, K.	116°30'E, 34°42'S
7.	C, Off Nelson Road, K.	116°29'E, 34°42'S
8.	C, Off Nelson Road, J.	116°26'E, 34°43'S
9.	M.P., Dog Road, S.F.	116°26'E, 34°43'S
10.	C, Dog Road, S.F.	116°25'E, 34°43'S
11.	Shannon River, Dog Road, K.	116°25'E, 34°43'S
12.	P on Nelson Road, S.F.	116°24'E, 34°43'S
13.	C, Nelson Road K.	116°24'E, 34°44'S
14.	C, Deeside Road, K.	116°20'E, 34°42'S
15.	C, Deeside Road, K.	116°20'E, 34°41'S
16.	Deep River, S.W. Hg/wy, K.	116°38'E, 34°59'S
17.	C, S.W. Hg/wy, K.	116°36'E, 34°58'S
18.	C, S.W. Hg/wy, L.F.	116°35'E, 34°56'S
19.	C, S.W. Hg/wy, L.F.	116°35'E, 34°56'S
20.	Inlet River, S.W. Hg/wy, J.	116°34'E, 34°55'S
21.	C, S.W. Hg/wy, L.F.	116°34'E, 34°54'S
22.	C, S.W. Hg/wy, S.F.	116°33'E, 34°53'S
23.	P, S.W. Hg/wy, L.F.	116°32'E, 34°48'S
24.	C, S.W. Hg/wy, J.	116°30'E, 34°46'S
25.	C, S.W. Hg/wy, K.	116°30'E, 34°44'S
26.	Weld River, S.W. Hg/wy, K.	116°31'E, 34°41'S
27.	Shannon River, S.W. Hg/wy, K.	116°24'E, 34°35'S
28.	Quininup Brooke, Cripple Road, K.	116°17'E, 34°30'S
29.	C on Wheatley C. Road.	116°15'E, 34°26'S
30.	C. Gardner River Road.	116°12'E, 34°43'S
31.	Una Brook, Gardner River Road, K.	116°12'E, 34°44'S
32.	Buldonia Creek, Gardner River Road, J/M.	116°13'E, 34°46'S
33.	Boorara Brook, Boorara Road, J/M.	116°12'E, 34°41'S
34.	East Brook, Boorara Road, K.	116°17'E, 34°37'S
35.	Boorara Brook, Middleton Road, K.	116°13'E, 34°37'S
37.	Dombakup Brook, Vasse Hg/wy, K/M.	116°04'E, 34°35'S
38.	C, Barker Road, K/M.	115°54'E, 34°31'S
39.	Lake Yeagerup, Coastal J.	115°52'E, 34°32'S
40.	Lake Yeagerup, Coastal J.	115°53'E, 34°32'S
41.	C, Lake Road, J/M.	115°53'E, 34°31'S
42.	C, Ritters Road, K.	115°53'E, 34°30'S
43.	C, Lewin Road, J/M.	115°55'E, 34°36'S
44.	L, Lewin Road, J/M	115°54'E, 34°36'S
45.	C, Richardson Road, J/M.	115°57'E, 34°36'S
46.	C, Off Richardson Road, J/M	115°58'E, 34°37'S
47.	C, Richardson Road, J.	115°59'E, 34°38'S
48.	C, Richardson Road, J.	116°05'E, 34°38'S
49.	C, Thompson Road, J.	116°42'E, 34°40'S
50.	C, Thompson Road, L.F.	116°42'E, 34°44'S
51.	Elsie Brook, Thompson Road, J/M.	116°43'E, 34°51'S
52.	C, Bevan Road, S.F.	116°35'E, 34°35'S
53.	Deep River, Bevan Road, K.	116°33'E, 34°35'S
54.	C, Bevan Road, J.	116°32'E, 34°35'S
55.	C, Bevan Road, K.	116°30'E, 34°35'S
56.	Tone River, Muir Hg/wy, J.	116°53'E, 34°24'S
57.	M.P., Meribup Arboretum, L.F.	116°30'E, 34°23'S
58.	C, Denbarker Road, J.	117°33'E, 34°41'S
59.	C, Denbarker Road, C.F.	117°29'E, 34°45'S
60.	C, Denbarker Road, J.	117°27'E, 34°39'S
61.	Mitchell River, Denbarker Road, J/M.	117°24'E, 34°50'S
62.	C, Denbarker Road, J/M.	117°23'E, 34°55'S
63.	C, Summer time track, L.F.	116°04'E, 34°44'S
64.	Meerup River, Gurnsey Road, J.	116°04'E, 34°41'S
65.	C, Rifle Range Road, J.	116°01'E, 34°37'S
66.	C, Rifle Range Road, K.	116°01'E, 34°37'S
67.	C, Rifle Range Road, J.	116°03'E, 34°36'S
68.	C, Rifle Range Road, K.	116°03'E, 34°35'S
69.	Barlee Brook, Vasse Hg/wy, C.F.	115°45'E, 34°13'S
70.	C, Vasse Hg/wy, J.	115°46'E, 34°18'S
71.	Donnelly R., Vasse Hg/wy, C.F.	115°46'E, 34°19'S
72.	C, Jasper Road, J/M.	115°47'E, 34°22'S
73.	C, Jasper Road, J/M.	115°46'E, 34°23'S
74.	C, Pneumonia Road, L.F.	115°44'E, 34°25'S
75.	Carey Brook, Jasper Road, J.	115°48'E, 34°26'S
76.	Weld River, Beardmore Road, K/M.	116°34'E, 34°37'S
77.	Deep River, Beardmore Road, J/M.	116°35'E, 34°48'S
78.	Frankland River, Caldyanning Road, K.	116°48'E, 34°39'S
79.	C, Boronia Road, L.F.	116°50'E, 34°39'S
80.	C, Boronia Road, M.F.	116°51'E, 34°39'S
81.	C, Middle Road, M.F.	116°57'E, 34°50'S

82.	C, Middle Road, M.F.	116°57'E, 34°52'S
83.	Bow River, Middle Road, J/M.	116°58'E, 34°55'S
84.	C, Break Road, J/M.	117°03'E, 34°51'S
85.	Barlee Brook, Steward Road, J/M.	115°42'E, 34°19'S
86.	C, Steward Road, J/M.	115°42'E, 34°19'S
87.	M.P., Black Pt. Road, L.F.	115°40'E, 34°18'S
88.	M.P., Fouracres Road, L.F.	115°35'E, 34°18'S
89.	M.P., Fouracres Road, L.F.	115°35'E, 34°18'S
90.	M.P., Fouracres Road, C.F.	115°31'E, 34°18'S
91.	M.P., Scott Road, C.F.	116°16'E, 34°12'S
92.	M.P., Scott Road, C.F.	115°16'E, 34°11'S
93.	M.P., Scott Road, C.F.	115°16'E, 34°10'S
94.	C, Steward Road, J.	115°32'E, 34°11'S
95.	C, Steward Road, J.	115°35'E, 34°12'S
96.	M.P., Myalgelup Road, L.F.	116°43'E, 34°33'S
97.	Frankland R., Myalgelup, J.	116°51'E, 34°33'S
98.	M.P., Nornalup Road, C.F.	116°57'E, 34°35'S
99.	C, Nornalup Road, J.	116°57'E, 34°39'S
100.	M.P., Nornalup Road, S.F.	116°57'E, 34°44'S
101.	C, Nornalup Road, J.	116°57'E, 34°44'S
102.	Kent R., Basin Road, J.	117°03'E, 34°46'S
103.	C, Nornalup Road, J.	117°00'E, 34°50'S
104.	C, S.W. Hg/wy, C.F.	117°04'E, 34°58'S
105.	Kordabup Rd., S.W. Hg/wy, C.F.	117°09'E, 34°59'S
106.	C, S.W. Hg/wy, C.F.	117°12'E, 34°59'S
107.	C, S.W. Hg/wy, C.F.	117°18'E, 34°59'S
108.	C, S.W. Hg/wy, L.F.	116°53'E, 35°01'S
109.	M.P., Muir Hg/wy, C.F.	116°50'E, 34°28'S
110.	C, Muir Hg/wy, C.F.	116°57'E, 34°29'S
111.	C, Muir Hg/wy, C.F.	116°58'E, 34°29'S
112.	C, Muir Hg/wy, C.F.	116°59'E, 34°30'S
113.	Kent R. Bevan Road, J.	117°06'E, 34°41'S
114.	P. Kockelup Road, J.	117°08'E, 34°47'S
115.	Denmark R. Kockelup Road, K.	117°13'E, 34°47'S
116.	C, Kockelup Road, J.	117°14'E, 34°46'S
117.	C, Stan Road, J.	117°21'E, 34°48'S
118.	C, Stan Road, J.	117°21'E, 34°51'S
119.	C, Court Road, K.	115°56'E, 34°20'S
120.	M.P., Glouster Road, K.	116°08'E, 34°21'S